ENERGY EFFICIENCY AND CONSERVATION: A PARADOX

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Abstract

The main objective of energy and climate policy in recent years has been to reduce energy usage, often by encouraging the increased energy efficiency of existing technologies. Some economists, however, postulate that increased technology efficiency actually leads to greater energy consumption. Such an outcome is predicted by the scenario known as Jevons' Paradox. Our study examines the possible effects of Jevons' Paradox at the microeconomic level via a multiple linear regression analysis to determine whether or not the increased usage of Energy Star appliances—a class of high-efficiency appliances approved by the U.S. government—leads to an increase or decrease in energy consumption per household. We then use our results to assess the effectiveness of the Energy Star program in decreasing energy consumption.

Introduction

For the last few decades, energy and climate policy have been high on the global agenda. The main objective of these complementary policy branches has been to reduce energy usage, particularly fossil fuel usage, in order to mitigate adverse effects on the environment. The main method of reducing energy usage has been to increase the efficiency of everyday technologies rather than to incentivize citizens to reduce their consumption (Nick Hanley 2009). While these two approaches may at first seem like two sides of the same coin, economists continue to debate the case. Many postulate that increased technology efficiency actually leads to greater energy consumption. Savings generated by increased output per unit of energy could result in increased usage of energy through several alternative routes. These routes include direct consumption of more energy via the income effect, increased consumption of other goods requiring energy via the substitution effect, and economic growth due to productivity gains. These outcomes could result in either no reduction in energy consumption despite increased efficiency, or even in increased consumption because of it. This possible increase in consumption as a result of increased efficiency is known as Jevons' Paradox, and it is this paradox that our paper seeks to further explore.

Jevons' Paradox

In 1865 the British economist William Stanley Jevons first postulated what has come to be known as *Jevons' Paradox* (Sorrell 2009). This paradox hypothesizes that technologies with higher energy efficiency will, rather than decrease energy consumption, actually increase it. Jevons constructed this hypothesis after observing that as coal usage in producing iron decreased, the use of iron increased. Unfortunately, in the modern era such a clear connection has not been found. Most explorations of Jevons' Paradox explore this phenomenon at the microeconomic level for various technologies via multivariate regression modeling. While these models have produced some evidence in favor of the paradox's existence, they have yet to draw truly sound conclusions, since the paradox exists on multiple economic levels (macro and micro) and varies in its effect over time.

Our Contribution

Our paper examines the possible effects of Jevons' Paradox at the microeconomic level. We carry out a multiple linear regression to determine whether or not the increased usage of Energy Star appliances leads to an increase in energy consumption by households. Our null hypothesis is that Energy Star appliance ownership has no impact on electricity consumption. Our alternative hypothesis is that Energy Star appliance ownership correlates with increased electricity consumption. We then use our results to assess the effectiveness of the U.S. Energy Star program in directly decreasing energy consumption and discuss the wider policy implications of our study. We chose to focus on the direct effect of energy star appliances as most studies we encountered ignored this effect altogether. That is, most studies did not bother establishing the whether or not more efficient technologies promoted energy conservation in the short term. Rather, they jumped straight to assessing long term effects, and drew conclusions from there.

This research is unique in that, to our knowledge, no papers on Jevons' Paradox have investigated whether Energy Star appliance ownership leads to higher energy consumption or not. We feel that the microeconomic implications of examining Jevons' Paradox, whether or not the paradox is found to exist, will have profound implications for the direction and purpose of energy consumption policies for both the Energy Star program and other efforts aimed at increasing energy efficiency and reducing energy consumption.

Literature Review

The "Myth" of Technological Liberation? Research from Sienna College

Polimeni and Polimeni (2006) model the relationship between changes in energy consumption and changes in efficiency. They draw inspiration from Ehrlich and Holdren's *I=PAT* model and apply their two adapted models to six macroeconomic regions across the globe (see equations A and B). In these models, energy consumption *I* was the dependent variable, population growth and size were *P*, consumption per person is *A*, and environmental deterioration was *T*. The first model included population growth, while the second did not. Data for these variables were situated within a time-series cross sectional (TSCS) regression model. The authors cite increased variability, removal of heterogeneity problems, and allowance for study of both spatial and temporal aspects of a model as reasons for using TSCS (John M. Polimeni 2006, 346).

A) $EC = \beta_1 + \beta_2\%\Delta GDP + \beta_3\%\Delta EI + \beta_4\%\Delta P$

B) $EC = \beta_1 + \beta_2\%\Delta GDP + \beta_3\%\Delta EI$

However, downsides to the model were also noted. Namely, the model's "regression estimates" were biased, errors were correlated, and, finally, heteroskedasticity was likely. These issues were present due to temporal correlation amongst independent variables, and the fact that variances were unlikely to be consistent across the regions included. Finally, the model does not produce a goodness-of-fit measure. In sum, the study sacrificed precision in order to conduct a macro-level analysis. Heteroskedasticity and multicollinearity were rife in the models, causing them to fail frequently. In addition, micro-level information such as the specific type or age of the technology could not be controlled for. While initial macro-level results were promising, micro-level factors were not well accounted for, and this limits the models' explanatory strength.

Zero Energy Buildings and the Rebound Effect

Bourrelle (2014) addresses the problem of the rebound effect at a microeconomic level, specifically as associated with the construction of zero energy buildings (ZEBs). ZEBs are buildings designed to maximize energy efficiency and utilize renewable energy resources for any energy inputs they require. Bourrelle utilizes E2 (economy-environment) vectors to compare conventional buildings with ZEBs and to illustrate the possible rebound effects associated with ZEBs under different scenarios. The vectors show each building's cumulative value on the x-axis and nonrenewable energy cost on the y-axis. From these vectors, Bourrelle concludes that energy efficient buildings result in greater cost savings than conventional buildings. This, however, leaves significant savings that will be re-spent. This money could easily be re-spent on high energy consumption technologies, a phenomenon known as the rebound effect. That said, if money saved by increased efficiency were invested in renewable energy sources, the rebound effect would be lessened. For example, Bourrelle notes that advantageous feed-in tariffs could result in higher rebound effects. He also notes that the type of renewable energy source used by a ZEB influences the size of the rebound effect: more effective sources, such as solar panels in a sunny area, result in lower rebound effects. Although the paper focuses on zero energy buildings in Norway rather than on the use of energy efficient appliances in the United States, its proposed solution of lessening or even dispensing with the rebound effect by encouraging the investment of re-spent gains from ZEBs in renewable energy sources could be applied to gains from energy efficient appliances as well.

Irrigation Efficiency and Water Usage

Carlos Gómez and Carlos Gutierrez (2011) conducted a microeconomic study on water usage and irrigation efficiency by Mediterranean farmers. In their study, they explored the marginal cost of water usage, the income effect, and the substitution effect with regard to a series of technological innovations in irrigation. As part of their experiment, they derived the demand equation for water by Mediterranean farmers. By their calculations, given *any* improvement in irrigation technology, the farmers' demand curve will shift outward. The researchers drew two important conclusions: the first regarding a quantity effect, the second a price effect. The quantity effect observed was that given the technological innovations in question, water required to produce a given level of output was lower than without the technological innovation. The price effect observed was that the marginal cost of water was lower with the technological innovation. Less water yielded more crops. Combined, the observed quantity and price effects depend on the elasticity of farmers' demand for water. In sum, the researchers found sound evidence at the microeconomic level for Jevons' Paradox in Mediterranean irrigation practices.

Environmental Rebound Effect

Vivanco, Freire-Gonzalez, Kemp, and van der Voet (2014) discuss the rebound effect as applied to plug-in-hybrid electric, full-battery electric, and hydrogen fuel cell cars in Europe. Rather than looking at how the usage of these technologies effects energy consumption, however, they examine their environmental rebound effect. The environmental rebound effect was measured by looking at factors such as global warming potential, acidification potential, and freshwater eutrophication potential. This allowed the researchers to examine change in a product on a broader level than just energy efficiency, since technological advancements leading to changes in levels of "GHG or toxicity efficiency" can also be considered. The authors created four models to examine the possibility of a rebound effect from the use of the three types of automobiles. These models examined both the direct effect as well as the indirect effect of utilizing these technologies. They concluded that there was a small positive rebound effect for plug-in hybrid electrics, since the technology is relatively cheap and therefore frees up money for the consumer to spend on other things that negatively impact the environment. Full battery electric and hydrogen fuel cell automobiles, however, both had negative environmental rebound effects. The authors believed that this was due to the fact that these technologies were more expensive, implying that income that could have been spent on other products with negative environmental impacts was instead spent on purchasing the technology in question. They noted that this has important implications for the pricing of efficient technologies: if the price is higher, the rebound effect may be negative. Therefore, the technology would be more effective in reducing negative environmental effects than technologies with lower prices.

Our Contribution to Existing Literature

The United States ranks second in the world for energy consumption, and yet we found very few papers researching Jevons' Paradox in the American economic context (Central Intelligence Agency, n.d.). Our paper will seek to widen the literature on Jevons' Paradox in the U.S. by exploring the paradox via the U.S. Energy Information Administration's 2009 Household Survey. This survey consists of microeconomic observations collected from all across the United States, and has variables concerning the federal Energy Star program. These Energy Star variables will be the primary focus of our analysis. Unlike other papers, our research will examine Jevons' Paradox in an American, microeconomic context and conclude by offering implications for U.S. policymakers concerned with both the success of the Energy Star program specifically and energy efficiency efforts in general.

Data

Our study seeks to determine whether or not increased energy efficiency leads to increased electricity consumption at a microeconomic level. Specifically, we examine Energy Star appliance use and its effects on the consumption of electricity in the residential sector of the United States. We chose to analyze Energy Star appliances because they not only provide a means of measuring the level of energy efficiency in the residential sector (since Energy Star appliances are designed to meet higher government standards) but also because of the policy implications that could stem from the results of a study of whether or not Jevons' Paradox holds true for these appliances. Namely, if Jevons' Paradox holds true, and a substantial rebound effect results from using Energy Star appliances, the government should reevaluate its design and use of the program. To carry out our study, we made use of cross-sectional data obtained from the 2009 U.S. Energy Information Administration's Residential Energy Consumption Survey, which includes over 931 indicators for over 12,000 households.

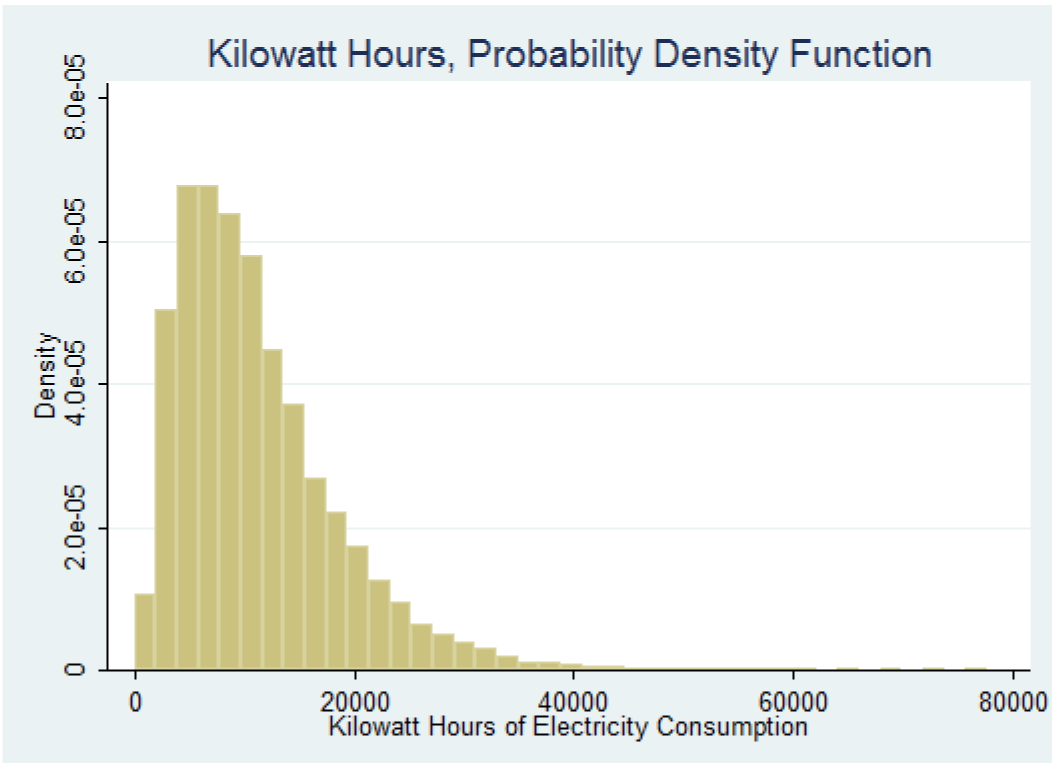
We carried out a multiple linear regression, using electricity consumption measured in kilowatt hours as our dependent variable (see Table 1). While the standard deviation and variance for the Kilowatt Hours variable seemed quite high, the distribution of the variable was in fact exactly as to be expected, other than one outlier variable which we dropped (see Figure 1). Our independent variables were used to gauge energy efficiency. We tested each of four Energy Star appliances as categorical variables, with the use of a given Energy Star appliance coded as a 1, the use of non-Energy Star appliance coded as 0, and no use of the appliance coded as a -2. The Energy Star appliances considered in our data as independent variables were Energy Star clothes washers, refrigerators, dishwashers, and air conditioning units used by a household. Our null hypothesis was that households using a given Energy Star did not differ from households using no Energy Star appliances, in terms of electricity consumption. In keeping with the ideas set forth in Jevons' Paradox, our alternative hypothesis was that households using a given Energy Star appliance use more electricity than households not using that Energy Star appliance

Table 1 Descriptive Statistics of the dependent variable Kilowatt Hours

STATISTIC	VALUE
MEAN	11276.66

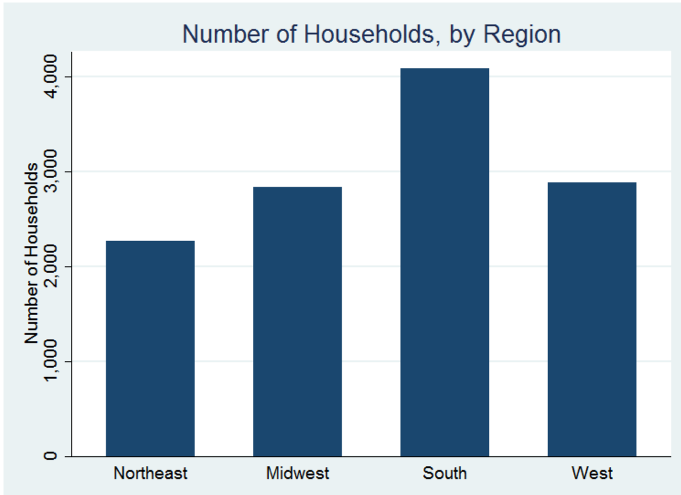
STANDARD DEVIATION	7536.179
VARIANCE	5.68 x 10^7

Figure 1 Probability Density Function of the Dependent Variable Kilowatt Hours



We examined a number of other independent variables as well in order to control for their effects on electricity consumption of a household. The control variables utilized included the type of housing unit, region in which unit is located, income, and education as control variables. Since air conditioning units should be used more intensively in a large residential home and less in a small studio apartment in the city, we controlled for type of housing unit. Energy prices differ significantly by area, so although we could not control for an exact electricity price, we were able to control for census regions within the US (see Figure 2). Income was controlled for as well, as it is a determining factor in a consumer's budget constraint, influencing how much a consumer spends and what they spend on. We also controlled for education in order to account for the way in which people with differing levels of education make different decisions. For example, education could be used as a proxy to measure level of awareness of environmental issues. People with higher levels of education may use more electronics for work and leisure, leading to a higher consumption of electricity. Our inclusion of this variable into our model controls for these possible effects.

Figure 2 Number of Households, by Region: As you can see, the region "South" comprises the largest share of responses, while the region "Northeast" comprises the smallest. The regions "West" and "Midwest" had approximately equal response rates.



Our model held to each of the 5 Gauss Markov assumptions, as outlined by Woolridge (2009). Our variables were linear in parameters as there are no restrictions on the relationships between x, y, and the variables of interest. Our data was a random sample as the U.S. Information collected data from different households across the U.S. in a random manner. None of our variables correlated *perfectly*, though several control variables did correlate somewhat with one another. We have taken what we consider to be the variables with the most explanatory power out of *u*, the error term, leaving the expected value of *u* to be zero. Finally, we assumed homoskedasticity, a constant error value given any independent variable as there was no evidence to the contrary. As such, our models are in line with the Gauss Markov assumptions.

Results

Simple Regression

Model 1

We chose to run a simple regression of Energy Star clothes washer ownership over Kilowatt Hours of electricity used. We chose to use the variable for Energy Star washers rather than any of the other Energy Star variables as, based on the literature we had read, many respondents owned washers, and washers tend to consume large amounts of electricity. Based on this information, we decided that washing machine ownership was most likely to exhibit evidence of Jevons' paradox.

Table 2 shows the results from this simple regression. Energy Star clothes washer ownership was significant for the 95% confidence level, the P>|t| value was less than .05, and the t value was very high. From the coefficient, it can be seen that Energy Star washer ownership has a positive correlation with Kilowatt Hour electricity usage. That is, owning an Energy Star washer correlates with higher energy usage.

Equation 1

$$Kilowatt\ Hours = \beta_0 + \beta_1 ESWasher$$

Table 3: Simple Regression of Kilowatt hours over Energy Star Clothes Washer

KILOWATT_HOURS	COEFFICIENT	STANDARD ERROR	T	P>|T|	95% CONFIDENCE INTERVAL	R^2, UNADJUSTED
ESWASHER	1408.79	49.74972***	28.32	0.000	1311.272 to 1506308	0.0658
_CONS	11832.4	71.21504	166.15	0.000	11692.8 to 11971.99	0.0658

*t-statistics significant at 10%, **5%, ***1%

Multiple Regression

Model 2

Our first multiple regression (but second model) returned promising results. Nearly all of our independent variables proved significant, with P>|t| less than .05 for the 95% confidence interval. Only the variable representing Energy Star refrigerators proved insignificant. This could have occurred because, unlike the other appliances examined, refrigerators are generally turned on at all times regardless of their efficiency level. As such, there is no efficiency incentive one way or the other. In addition, our unadjusted R^2 value was 18.74%. Normally, this value would indicate that the model has moderate explanatory power. However, our model had seven highly significant variables at the 95% confidence interval, but did not reach even 20% explanatory power. This indicated to us that either the relationship depicted was nonlinear, or that one of the Gauss Markov assumptions may have failed. The inclusion of other independent variables such as the number of household members and other sources of electricity consumption could help raise the explanatory power of this model. We explored an expanded version in our third regression model.

We tested for multicollinearity by analyzing correlation between the Energy Star variables. As we had included several Energy Star appliance metrics separately, we were concerned that multicollinearity might be at play, especially with the strong significance of each individual variable but low overall explanatory power of the model. However, according to the correlation test in Table 3, our fears were unwarranted. None of our variables approached the benchmark of 90% correlation given in by Woolridge (2009). The strongest observed correlation between Energy Star variables (other than the variable's correlation with itself) was that between Energy Star refrigerators and Energy Star dishwashers at .3148, which does not even begin to approach the upper and lower bounds of the independence interval of $-1 \leq \text{Correlation}(X, Y) \leq 1$.

Table 3 Correlation test between Energy Star variables

	ESWASHER	ESFRIDGE	ESDISHWASHER	ESAIRCONTIONER
ESWASHER	1.0000	.	.	.
ESFRIDGE	0.2864	1.0000	.	.
ESDISHWASHER	0.2967	0.3148	1.0000	.
ESAIRCONTIONER	-0.0538	0.0394	-0.1139	1.0000

Although our correlation test showed no signs of multicollinearity in the model, we proceeded to conduct the F test to analyze the joint significance of our energy star variables. For our unrestricted model, we used the regression model seen in Table 4 and Equation 2. For our restricted model, we used the model seen in Table 5 and Equation 3 in which we dropped Energy Star Refrigerator and Energy Star Clothes Washer, but kept Energy Star Air Conditioner and Energy Star Dishwasher. The reasoning behind this is that it is easier to adjust how often you use your dishwasher and air conditioner than your refrigerator or clothes washer: a refrigerator will always be on, as otherwise the food will go bad, and similarly, very few people in the U.S. today are willing to set aside the amount of time necessary to hand-wash clothes. Most people do not even hand-wash the clothes that say "hand-wash only!" However, there are alternate means of staying cool than making the air conditioner work harder-- for example, wearing lighter clothing, drinking cold beverages, or opening windows to let in a breeze. Similarly, some people still choose to hand-wash their dishes or use disposable dinnerware, rather than use their dishwasher. By this logic, our restricted model dropped the Energy Star Refrigerator and Energy Star Clothes Washer variables, but kept the rest.

Equation 2 Unrestricted Regression Model

$$Kilowatt\ Hour = \beta_0 + \beta_1(TypeHousingUnit) + \beta_2(Region) + \beta_3(ESWasher) + \beta_4(ESFridge) + \beta_5(ESDishWasher) + \beta_6(ESAirConditioner) + \beta_7(Income) + \beta_8(Education)$$

Equation 3 Restricted Regression Model

$$Kilowatt\ Hour = \beta_0 + \beta_1(TypeHousingUnit) + \beta_2(Region) + \beta_3(ESDishWasher) + \beta_4(ESAirConditioner) + \beta_5(Income) + \beta_6(Education)$$

Table 4 Multiple Regression over Kilowatt Hours, Unrestricted Model

KILOWATT_HOURS	COEFFICIENT	STANDARD ERROR	T	P>|T|	95% CONFIDENCE INTERVAL	R^2, UNADJUSTED
TYPEHOUSINGUNIT	-1753.254***	60.2831	-29.08	0.000	-1871.421 to -1635.088	.1874
REGION	376.11***	65.25411	5.76	0.000	248.1993 to 504.0208	.1874
ESWASHER	549.1146***	54.96752	9.99	0.000	441.3675 to 656.8616	.1874
ESFRIDGE	-79.32978	56.4383	-1.41	0.160	189.9598 to 31.30028	.1874
ESDISHWASHER	668.7095***	56.6644	11.80	0.000	557.6362 to 779.7827	.1874
ESAIRCONDITIONER	-453.4494***	69.82464	-6.49	0.000	590.3193 to -316.5795	.1874
INCOME	126.7184***	11.69316	10.84	0.000	103.7976 to 149.6393	.1874
EDUCATION	-159.4722***	44.37932	-3.59	0.000	-246.4643 to -72.48009	.1874
_CONS	13886.64	327.8642	42.35	0.000	13243.96 to 14529.32	.1874

*t-statistics significant at 10%, **5%, ***1%

Table 5 Multiple Regression over Kilowatt Hours, Restricted Model

KILOWATT_HOURS	COEFFICIENT	STANDARD ERROR	T	P>|T|	95% CONFIDENCE INTERVAL	R2 , UNADJUSTED
TYPEHOUSINGUNIT	-1891.799***	55.80231	33.90	0.000	2001.181 to -1782.416	0.1801
REGION	413.1033***	62.90139	6.57	0.000	289.8056 to 536.401	0.1801
ESDISHWASHER	760.9804***	51.60822	14.75	0.000	659.8192 to 862.1415	0.1801
ESAIRCONDITIONER	-480.3827***	66.99159	-7.17	0.000	-611.6979 to -349.068	0.1801
INCOME	148.9574***	11.23822	13.25	0.000	126.9285 to 170.9863	0.1801
EDUCATION	-195.4455***	42.89452	-4.56	0.000	-279.5262 to -111.365	0.1801
_CONS	13838.21	315.9276	43.80	0.000	13218.94 to 14457.48	0.1801

*t-statistics significant at 10%, **5%, ***1%

The equation for the F test is given by Equation 4. Using the values obtained in Tables 4 and 5, and formula given in Equation 4, we obtained a value of 9.7175 for our F statistic. When compared to the critical value of 1.83 at the α = .05 level, the calculated F statistic was clearly greater. As such, our null hypothesis that Energy Star appliances had no effect on energy consumption was rejected. The variables we selected for our first multiple regression model do, indeed, have joint significance and do not suffer from multicolinearity.

Equation 4: Formula for calculating the F statistic

$$F = (\frac{(R^2_{unrestriced} - R^2_{restricted})/(Degrees\ Freedom_{restricted} - Degrees\ Freedom_{unrestricted})}{(1 - R^2_{unrestricted})/(Degrees\ Freedom_{unrestricted})}$$

Finally, the difference in the coefficients on Energy Star Dishwasher, Energy Star Air Conditioner, and Housing Unit Type between the unrestricted and restricted model each proved highly intriguing. Energy Star Dishwasher had a strong positive relationship with Kilowatt Hours in the unrestricted model, and the coefficient on this variable increased by nearly 100 kilowatt hours in the restricted model. Housing Unit Type had strong negative relationship with Kilowatt Hours in the unrestricted model, and this relationship increased by *over* 100 kilowatt hours in the restricted model. Energy Star Air Conditioner, on the other hand, did not change much at all between models. Its coefficient decreased by just under 30 kilowatt hours. This was not consistent with the other observed changes, nor was it what we had anticipated observing.

Model 3

In our third model, as shown in Equation 5, we added the number of household members as an independent variable, since more family members should mean that less electricity is consumed per capita. We also added the number of computers in a household as an independent variable as well as a dummy variable that shows whether or not there is a video game console hooked up to the most-used television in the house. Our reasoning for including these new independent variables is that they may help explain some of the variation observed in electricity consumption, since computers and video games are large sources of electricity usage. As these variables' values increased, we expected a corresponding increase in electricity consumption. Finally, we changed the dependent variable from electricity consumption to electricity consumption per capita.

Equation 5 Regression Model

$$\begin{aligned} &Kilowatt\ Hr\ per\ capita \\ &\quad = \beta_0 + \beta_1(TypeHousingUnit) \\ &\quad + \beta_2(Region) + \beta_3(ESWasher) + \beta_4(ESAirConditioner) + \beta_5(Income) \\ &\quad + \beta_6(Education) + \beta_7(videoGames) + \beta_8(numComputers) + \beta_9(familySize) \end{aligned}$$

Table 6 shows the results from the regression of model 3. In this model as well, the majority of our independent variables were significant at the 95% confidence interval, as shown by the fact that they had P>|t| values of less than .05. The only insignificant variables were income, education, and videogames. In model 2, income and education were significant, so the fact that they are insignificant using model 3 could be caused by the existence of multicollinearity in the model. That is, the dependent variable in this model is related to the independent variable family size, because we divided the number of kilowatt hours consumed in a household (our previous dependent variable) by family size to obtain our current dependent variable. Since the two variables are not, however, perfectly linearly related, our third model does not violate the Gauss Markov assumptions. Furthermore, our third model has a higher explanatory power than our previous models, since our unadjusted R^2 value was 25.43% as opposed to a value of 18.74% for our second model, or an R^2 value of 6.58% for our first model. This indicates that the model is better able to explain variation in the dependent variable than our previous models.

As in the model 2, the Energy Star dishwasher variable has a positive coefficient, meaning that electricity consumption per capita increases if a household has an Energy Star dishwasher, and the Energy Star air conditioner variable has a negative coefficient, implying the opposite result. With regards to coefficients of the new variables added to model 3, family size showed the strongest value (-1206.0087). This implies that an increase in family size leads to a strong decrease in electricity consumption per capita. This makes sense, since many appliances can be used by all family members at once (such as a television or an air conditioner). A one-person household using the air conditioner would consume the same amount of energy as an entire family, so energy use per capita should be smaller as family size rises. Family size was highly significant at all levels, with a t-value of -53.41. An increase in number of computers, on the other hand, led to an increase in electricity consumed per capita, also as expected.

Table 6 Multiple Regression over Kilowatt Hours per Capita

KILOWATT_HOURS_PER_CAPITA	COEFFICIENT	STANDARD ERROR	T	P>|T|	95% CONFIDENCE INTERVAL	R2 , UNADJUSTED
TYPEHOUSINGUNIT	-803.7182***	27.78719	-28.92	0.000	-858.1859 to -749.2504	0.2543
REGION	247.4511***	31.0563	7.97	0.000	186.5753 to 308.3269	0.2543
ESDISHWASHER	239.8665***	25.60239	9.37	0.000	189.618 to 290.0517	0.2543
ESAIRCONDITIONER	-259.3968***	33.09404	-7.84	0.000	-324.2669 to -194.5267	0.2543
INCOME	1.648131	5.818405	0.28	0.777	-9.756958 to 13.05322	0.2543
EDUCATION	-56.87238***	21.94263	-2.59	0.010	-99.88376 to -13.86099	0.2543
VIDEOGAMES	77.35534	64.38684	1.20	0.230	-48.85409 to 203.5648	0.2543
NUMCOMPUTERS	179.6374***	31.67522	5.67	0.000	117.5484 to 241.7263	0.2543
FAMILY SIZE	-1206.087***	22.58335	-53.41	0.000	-1250.354 to -1161.819	0.2543

_CONS	9507.278	168.5774	56.40	0.000	9176.837 to 9837.719	0.2543

*t-statistics significant at 10%, **5%, ***1%

We ran a correlation test to see if any of the new variables in Model 3 were strongly correlated, but as in Model 2, the variables tested had low correlation with one another (see Table 7). The highest correlation between these variables was 0.2656, which was between the number of computers and family size. Due to the lack of multicolinearity in model 2, which had greater correlation between variables, we deemed conducting an F test here to be unwarranted.

Table 7 Correlation test between Energy Star variables

	VIDEO GAMES	**NUM COMPUTERS**	**FAMILY SIZE**	**ESDISH WASHER**	**ESAIR CONDITIONER**
VIDEOGAMES	1.0000				
NUMCOMPUTERS	0.1861	1.0000			
FAMILYSIZE	0.2284	0.2656	1.0000		
ESDISHWASHER	0.0936	0.2651	0.0843	1.0000	
ESAIRCONDITIONER	0.0242	-0.0290	0.0376	-0.1110	1.0000

Conclusion

In sum, Energy Star appliance ownership proved an extremely significant predictor of electricity consumption. However, the sign of the coefficient differed depending on the appliance. This seems to indicate that some appliances are helpful in reducing energy consumption, while other actually encourage increased energy consumption. Energy Star refrigerators and air conditioners proved helpful in reducing electricity use, while Energy Star dishwashers and clothes washers did not. Each of these variables, with the exception of refrigerators, proved significant at the 90%, 95%, and 99% confidence intervals. We focused primarily on the role of Energy Star dishwashers and air conditioning units as we felt appliance owners would be more likely to vary their usage of these appliances due to seasonal factors and personal preference. Our alternative hypothesis that electricity consumption would increase with Energy Star appliance ownership proved correct with regard to Energy Star clothes and dish washers. This could be due to people simply running smaller loads of clothes and dishes more frequently because of the increased efficiency, which decreases the appliance owner's effective price per load. This is in fact evidence in favor a short-term presence of Jevons' Paradox in certain Energy Star appliances.

Future research should be certain *not* to combine Energy Star appliances into a single categorical variable, as we have proven here that separate appliances have separate effects, likely due to differences in usage habits. The Energy Star program should, therefore, more closely examine individual household appliance usage habits in order to determine whether or not certain appliances, though more energy efficient, should be included in the Energy Star category, as their inclusion could encourage more energy consumption, rather than less. This can be accomplished by employing smart meter technology at the household level. Smart meters track and record data on electricity consumption in individual homes. In addition, the government should examine its pricing and incentive strategy on Energy Star appliances since, as mentioned in Vivanco, Freire-Gonzalez, Kemp, and van der Voet (2014), higher pricing reduces the amount of money consumers have to spend on other energy intensive goods.

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